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CROSS-COUNTRY INEQUALITY TRENDS*

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I review the two most popular explanations for the differential trends in wage inequality in US/UK and Europe: that relative supply of skills increased faster in Europe, and that European labour market institutions prevented inequality from increasing. Although these explanations go some way towards accounting for the differential cross-country inequality trends, it also appears that relative demand for skills increased differentially across countries. I develop a simple theory where labour market institutions creating wage compression in Europe also encourage more investment in technologies increasing the productivity of less-skilled workers, implying less skill-biased technical change in Europe than the US.

While over the 1980s wage inequality and returns to education increased sharply in the US and the UK, there was less of an increase, or even no change, in continental European economies; see, for example, Freeman and Katz (1995), Nickell and Bell (1996), Katz *et al.* (1995).

Table 1 illustrates these trends by showing an estimate of the education premium and the log differences of the 90th and the 10th percentiles of the wage distribution for a number of countries from the Luxembourg Income Studies dataset (and for the US from the CPS, see Section 3 and the Appendix for data details). The Table also replicates the estimates of the 90–10 differential for a number of countries from Table 2 of the survey by Freeman and Katz (1995) for comparison. The numbers show that US inequality and skill premia were higher at the end of the 1970s than in most other countries, and from there on, they increased faster than in these other cases (perhaps with the exception of Israel).

These cross-country trends are wellknown. There is also a fairly widespread consensus that US wage inequality rose because the relative demand for skills increased faster than the relative supply, most likely due to rapid skill-biased technical change and perhaps also due to increased international trade, for example, Katz and Murphy (1992), Berman *et al.* (1994), Katz and Autor (1999), Acemoglu (2002*a*). So why have the same technological developments not increased skill premia in much of continental Europe?

There are three broad types of answers:

1. The relative supply of skills increased faster in Europe.
2. European wage-setting institutions prevented wage inequality from increasing.
3. Due to differences in technical change or openness to international trade, demand for skills has increased less in Europe than in the US and the UK.

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Table 1a

(*a*) *Log 90^{th}–10^{th} Wage Differential for Male Workers, Selected Countries*

	Estimates using LIS data						Estimates reported by Freeman and Katz (1995)			
	Early 80s	Mid 80s	Late 80s	Early 90s	Mid 90s	Late 90s	Early 80s	Mid 80s	Late 80s	Early 90s
Australia		0.834	0.920				0.69	0.76	0.77	0.80
Belgium		0.780	0.773	0.762		0.697				
Canada			1.116	1.182	1.160	1.254	1.25	1.39	1.34	1.38
Denmark			0.913	1.307	1.096	1.059				
Finland			0.899	0.893	0.862					
Germany	0.819	0.894	1.186		1.043			0.96	0.91	
Israel	1.280	1.481		1.557						
Netherlands	0.876		0.907	0.864	0.843		1.01			1.01
Norway		0.810		0.913	1.122					
Sweden	0.867		0.920	0.864	0.880		0.77	0.72	0.72	0.77
UK	0.930	1.093		1.109	1.143		0.88	1.04	1.10	1.16
US	1.253	1.409	1.427	1.442	1.551	1.465	1.23	1.36	1.38	1.40

Note: The data for the left panel come from the Luxembourg Income Studies Database, a collection of macro datasets obtained from annual income surveys.
The log 90^{th}–10^{th} wage differential is the difference between the 90^{th} and the 10^{th} percentiles of the log wage distribution for male workers.
In the left half of the Panel, *Early 80s* refers to 1981, with the exception of Israel and the UK, where it refers to 1979 and the Netherlands, where it refers to 1983. *Mid 80s* refers to 1985 for Austria, Belgium and the US, and to 1986 for Israel, Norway and the UK. *Late 80s* refers to the 1987 except for Belgium and the US, where it refers to 1988, and for Austria and Germany, where it refers to 1989. *Early 90s* refers to 1991, except for Belgium, Denmark, Israel and Sweden, where it refers to 1992. *Mid 90s* refers to 1995, except for Canada, Germany and the Netherlands, where it refers to 1994. *Late 90s* refers to 1997. The right panel uses data from Table 2 of Freeman and Katz (1995). Here, *Early 80s* refers to 1979, except for Canada and Sweden, where it refers to 1981. *Mid 80s* refers to 1984, except for Australia and Sweden, where it refers to 1985, and for Canada, where it refers to 1986. *Late 80s* refers to 1987, except in Canada and Sweden, where it refers to 1988. *Early 1990s* refers to 1990, except in Sweden, where it refers to 1991.

The first two explanations have been the most popular among economists, and I refer to them as the 'traditional explanations'. Both of these explanations fit nicely into the relative-supply-demand framework, which has been a very useful tool in understanding the US wage inequality patterns. They both suggest that the lack of increase in inequality in Europe should have been associated with a relatively faster increase in the employment of more skilled workers. Table 1 shows that during the 1980s the relative *employment* of skilled workers increased faster in a number of European countries than in the US. Is this more rapid increase in skilled employment sufficient to account for the stability of the European wage structure?

In the first part of the paper, I use a version of the relative-supply-demand framework to investigate this question. The evidence suggests that *with similar shifts in relative demand for skills across countries,* differential changes in the relative employment of skilled workers, either because of differences in relative supplies or differences in relative unemployment rates, account for a significant component of the differential inequality trends. Nevertheless, it also appears that the relative demand for skills did not increase as much in many European

Table 1b

(b) Estimated Skill Premia and Relative Supplies for Male Workers, Selected Countries

	Skill premia						Relative skill supplies					
	Early 80s	Mid 80s	Late 80s	Early 90s	Mid 90s	Late 90s	Early 80s	Mid 80s	Late 80s	Early 90s	Mid 90s	Late 90s
Australia		0.253	0.286					0.154	0.192			
Belgium		0.350	0.312	0.350		0.311		0.105	0.102	0.104		0.119
Canada			0.265	0.359	0.311	0.321			0.241	0.224	0.247	0.256
Denmark			0.335	0.336	0.279	0.247			0.186	0.217	0.199	0.189
Finland			0.347	0.383	0.373				0.090	0.097	0.125	
Germany			0.290		0.301				0.122		0.155	
Israel	0.267	0.339		0.231			0.205	0.222		0.290		
Netherlands	0.307		0.202	0.254	0.266		0.087		0.153	0.282	0.337	
Norway		0.183		0.248	0.179			0.106		0.184	0.203	
Sweden	0.560		0.592	0.363	0.319		0.130		0.163	0.181	0.190	
UK	0.250	0.279		0.304	0.354		0.457	0.579		0.757	0.902	
US	0.271	0.362	0.387	0.454	0.514	0.518	0.233	0.268	0.281	0.303	0.350	0.355

Note: The data come from the Luxembourg Income Studies Database, a collection of macro datasets obtained from annual income surveys.
The skill premium is generally the coefficient on workers with a college degree or more relative to high school graduates in a regression of log real annual gross wages on four education categories and a quartic in age for full-time, full-year workers aged 18 to 64 – except in Sweden and the UK, where returns to broad occupations are used rather than education because no education information is available in the LIS data base for those countries. (See Appendix for more detailed information.)
The relative skill supply is the ratio of college graduates to non-college equivalents.
Early 80s, Mid 80s, etc. refer to the same years as in the left side of Panel (*a*).

economies as it did in the US and the UK. More specifically, I find that the relative-supply-demand framework, with the same relative demand shifts across countries, does a reasonable job of explaining some of the differences in the cross-country inequality trends, for example, for Finland and Norway. Nevertheless, there are a number of cases, in particular, Belgium, Denmark, and Sweden, and also to some degree Israel, where skill premia increased much less than predicted by this approach. I therefore conclude that the traditional explanations do not seem to provide an entirely satisfactory explanation for the differential inequality trends across countries. Instead, it appears that the US and European relative demand curves did not shift in the same way over the past 20 years.[1]

Given data quality and compatibility issues, this evidence has to be interpreted with caution. Nevertheless, it suggests that we should be thinking of explanations featuring differences in technical change or technology adoption across these countries. In the second part of the paper, I propose a possible explanation for

[1] Nickell and Layard (1999) also reach similar conclusions using a similar approach and different data sources; in particular, see their Table 24. Berman *et al.* (1998) look at patterns of skill-upgrading in various industries and conclude that there had been skill-biased technical change in all of the OECD countries in their sample. However, their results do not imply that these shifts have occurred at the same rate or with the same intensity across countries. In fact, to infer the overall rate of skill-biased technical change from industry data would require a variety of strong assumptions.

why relative demand for skills may not have increased as much in Europe as in the US. The basic idea is that institutional wage compression in Europe makes firms more willing to adopt technologies complementary to unskilled workers, making technical change less skill biased there.

The paper proceeds as follows. In the next Section, I review the three explanations suggested above. In Section 2, I develop a simple framework to investigate quantitatively whether cross-country inequality trends can be explained by the relative-supply-demand framework assuming similar changes in relative demand for skills across countries. In Section 3, I use data from the Luxembourg Income Studies (LIS) and undertake such an investigation. I find that although the differential behaviour of relative supplies between the US and continental Europe explains much of the differences, there is also evidence that the relative demand for skills did not increase as much in continental Europe. In Section 4, I make a preliminary attempt at developing a simple theory where relative demands change differentially across countries. Section 5 concludes.

1. Review of the Arguments

1.1. *Traditional Explanations of Differential Inequality Trends*

The traditional approaches explain the differential cross-country inequality trends by differences in the behaviour of relative supplies. The first explanation claims that the more rapid increase in the relative supply of skills in Europe accounts for the lack of increase in inequality there. The second explanation, on the other hand, emphasises the role of European wage-setting institutions. According to this explanation, it is not the differential growth of skilled workers in the population, but the differential behaviour of skilled employment that is responsible for differences in inequality trends across countries. More specifically, firms respond to wage compression by reducing their demand for unskilled workers, and the employment of skilled workers (relative to that of unskilled workers) increases in Europe compared to the US. As a result, the market equilibriates with a lower employment of unskilled workers compensating for their relatively higher wages in Europe.

Figure 1 illustrates the first explanation using a standard relative-supply-demand diagram, with relative supply on the horizontal axis and the relative wage of skilled workers, ω, on the vertical axis. For simplicity, I drew the relative supply of skills as vertical, thus taking the supply of skills to the economy as exogenous. The diagram shows that an increase in the demand for skills, for a given supply of skills, will lead to higher wage inequality. At a simple level, we can think of this economy as corresponding to the US, where the consensus is that because of skill-biased technical change or increased trade with less skill-abundant countries, the relative demand for skills grew faster than the relative supply during the recent decades. As a result of the increase in the relative demand for skills, the skill premium rises from ω^{Pre} to $\omega^{\text{US-Post}}$.

Now imagine that continental Europe is also affected by the same relative demand shifts, but the relative supply of skills also increases. This captures the

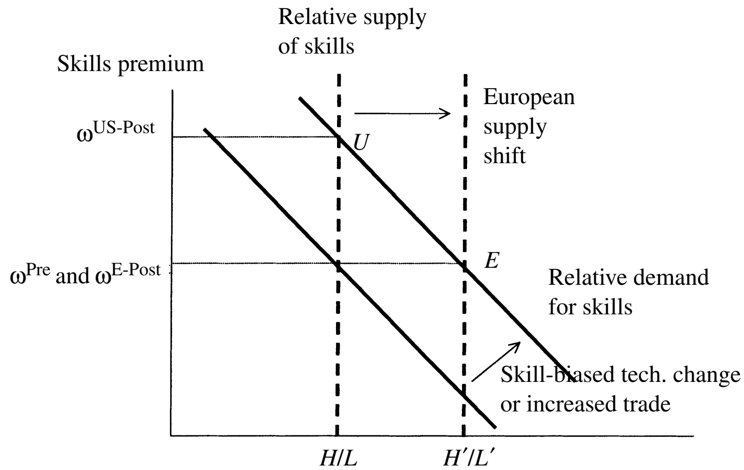

Fig. 1. *Differential Inequality Trends Due to Differential Relative Supply Changes*

essence of the first explanation, where the supply of skills increases faster in continental Europe than in the US. Then the 'European' equilibrium will be at a point like *E* which may not exhibit greater inequality than before. In fact, Figure 1 depicts the case in which there is no change in the skill premium in Europe.[2]

Probably the more popular explanation among economists and commentators is the second one above (Krugman, 1994; OECD, 1994; Blau and Kahn, 1996). To capture this story, imagine that wage-setting institutions in Europe prevent wage inequality from increasing — for example, because of union bargaining, unemployment benefits, or minimum wages that keep the earnings of low-skill workers in line with those of high-skill workers. This can be represented as an institutional wage-setting line different from the relative supply curve as drawn in Figure 2. (To make the story stark, I drew the institutional wage-setting line as horizontal.) The equilibrium now has to be along this institutional wage-setting line, and consequently *off the relative supply curve*, causing unemployment. Now, even in the absence of an increase in the relative supply of skills, the skill premium might not increase; instead there will be equilibrium unemployment. In the Figure, relative unemployment caused by the increase in the demand for skills is shown as the gap between the relative supply of skills and the intersection between relative demand and institutional wage-setting line. Notice that in the simplest version of the story, there is full employment of skilled workers, and the indicated gap simply reflects unskilled unemployment. The fact that

[2] See, among others, Katz *et al.* (1995), Gottschalk and Smeeding (1997), Murphy *et al.* (1998), Gottschalk and Joyce (1998), Leuven *et al.* (1999) and Card and Lemieux (2001). In particular, Leuven *et al.* (1999) show that using skill categories that are more comparable across countries significantly improves the fit of the relative-supply-relative-demand framework, and reverses some of the findings of the famous study by Blau and Kahn (1996).

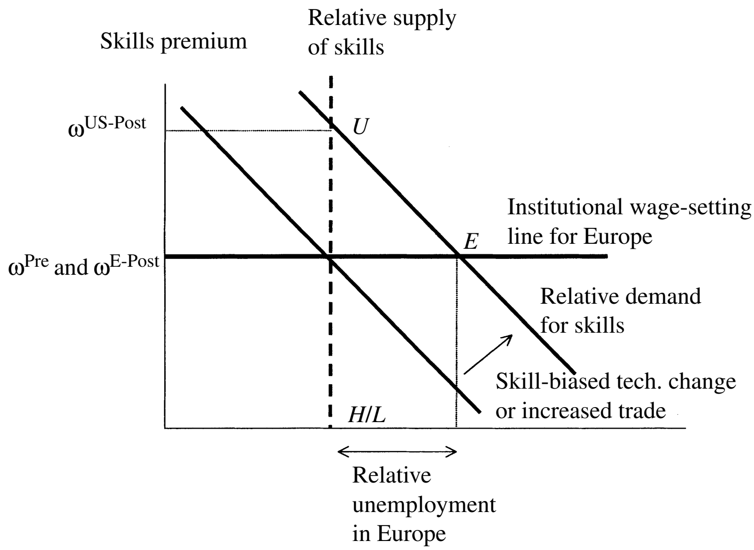

Fig. 2. *Differential Inequality Trends because of Differences in Labour Market Institutions*

unemployment increased in Europe relative to the US is often interpreted as evidence in favour of this explanation.[3]

The important point is that both of these explanations are 'supply-side'. Firms are along their relative demand curves, and different supply behaviour or institutional characteristics of the European economies pick different points along the relative demand curves.

This relative-supply-demand framework is not only a parsimonious specification, but also enables an empirical investigation of whether these two traditional explanations together can provide a satisfactory account for the behaviour of skill premia in continental Europe. According to these explanations, observed differences in the growth of relative employment of skilled workers should account for the differential behaviour of wage inequality in Europe. In Section 2, I develop a framework to investigate whether this is the case, and in Section 3, I present some empirical results using this framework.

1.2. *Differential Changes in the Relative Demand for Skills*

An alternative to the traditional explanations involves differential changes in the relative demand for skills across countries. Since most OECD economies likely have access, and even relatively rapid access, to the same set of technologies, the

[3] But in contrast to the prediction of this simple story, unemployment in Europe increased for all groups, not simply for the low-education workers. See, for example, Nickell and Bell (1996), Card *et al.* (1996) and Krueger and Pischke (1998). Nevertheless, some of the increase in unemployment among the high-education workers in Europe may reflect the effect of wage compression within education groups on job creation (e.g., if firms are forced to pay the same wages to low-skill college graduates as the high-skill college graduates, they may stop hiring the low-skill college graduates, increasing unemployment among college graduates).

most plausible reason for such differential changes would be *differences in technology adoption from a given world technology frontier*. In the last Section of the paper, I make a preliminary attempt to develop such a theory of differential adoption of available technologies.[4] Here I briefly summarise the main idea, leaving the details to that Section. The basic idea of the theory I propose is to link the incentives to adopt new technologies to the degree of compression in the wage structure, which is in part determined by labour market institutions. In particular, institutional wage compression in Europe makes firms more willing to adopt technologies complementary to unskilled workers, inducing less skill-biased technical change there.[5] This theory is based on three premises:

1. There is some degree of rent-sharing between firms and workers, for example, because of bargaining over quasi-rents.
2. The skill bias of technologies is determined by firms' technology choices.
3. A variety of labour market institutions tend to increase the wages of low-skill workers in Europe, especially relative to the wages of comparable workers in the US.

All three premises are plausible. The finding of high correlation between wages and firms' profitability or investments both in union and non-union sectors (Katz and Summers, 1989; Groshen, 1991; Blanchflower *et al.*, 1997) support the view that there is some amount of rent-sharing. That technology adoption is endogenous is close to the heart of many economists, and in previous work, Acemoglu (1998) and especially, Acemoglu (1999*a*), I developed this theme in detail and showed how it can help us understand the behaviour of the demand for skills and wage inequality in the US. Finally, the view that minimum wages, unions and social insurance programmes create wage compression in Europe and increase the pay of low-skill workers is widely shared by most economists, and supported by existing evidence (OECD, 1994; Blau and Kahn, 1996).

The new implication of combining these premises is that firms in Europe may find it more profitable to adopt new technologies with unskilled workers than their American counterparts. This is because with wage compression, firms are forced to

[4] Some alternatives, which I do not pursue here but are interesting areas for future research, are as follows:

1. Different countries may have experienced different degrees of trade opening, affecting the demand for skills differentially.
2. Local conditions may make it profitable for countries to develop some of their own technologies; see Acemoglu (1999*b*) for a model where advanced nations develop some of their own technologies and greater trade with skill-scarce LDCs may cause skill-biased technical change in the US, while inducing the development of more skill-replacing technologies in Europe.
3. Yet another alternative is to introduce labour market imperfections that would also force firms to function off their 'relative demand curves' (the model of Section 4 features labour market imperfections, but firms are still along their relative demand curves). An example would be efficient-bargaining between firms and unions. Nevertheless, even if firms are off their relative demand curves, they will be located along some equilibrium locus, and in this case we have to explain why this equilibrium locus is shifting differentially.

[5] An alternative theory of differential cross-country inequality trends is developed by Beaudry and Green (2000). They construct a model in which capital scarcity is more harmful to unskilled workers. The introduction of a new technology increases the demand for capital, and hurts unskilled workers. In Europe, capital is relatively more abundant than in the US, so the relative earnings of unskilled workers do not decline as much.

pay higher wages to unskilled workers than they would otherwise do (that is, greater than the 'bargained' wage, and because of rent sharing, they still find it profitable to employ some unskilled workers). This creates an additional incentive for these firms to increase the productivity of unskilled worker: they are already paying high wages, and additional investments will not necessarily translate into higher wages. Put differently, the labour market institutions that push the wages of these workers up make their employers *the residual claimant* of the increase in productivity due to technology adoption, encouraging the adoption of technologies complementary to unskilled workers in Europe.[6]

A simple numerical example illustrates this point more clearly. Suppose that a worker's productivity is 10 without technology adoption, and 20 when the new technology is adopted. Assume also that wages are equal to half of the worker's productivity, and technology adoption cost 6 (incurred solely by the firm). Now without technology adoption, the firm's profits are equal to $1/2 \times 10 = 5$, while with technology adoption, they are $1/2 \times 20 - 6 = 4$. The firm, therefore, prefers not to adopt the new technology because of the subsequent rent-sharing. Next suppose that a minimum wage legislation or a union-imposed wage floor requires the worker to be paid at least 9. This implies that the worker will be paid 9 unless his productivity is above 18. The firm's profits without the new technology now change to $10 - 9 = 1$, since it has to pay 9 to the worker because of the minimum wage. In contrast, its profits with technology adoption are still 4. Therefore, the firm now prefers to adopt the new technology. The reason for this change is clear: because of the institutionally-imposed wage push, the firm was already forced to pay high wages to the worker, even when his marginal product was low, so it became the effective residual claimant of the increase in productivity due to technology adoption.

This reasoning implies that there may be greater incentives to invest in technologies complementing workers whose wages are being pushed up by labour market institutions. Since European labour market institutions increase the pay of low-skill workers, technology may be endogenously less skill biased in Europe than in the US.[7]

An additional implication of this model is that institutional wage compression will make job creation less profitable in Europe, thus as in the second explanation above, we expect unemployment in Europe to increase relative to the US. Interestingly, in this story, the rise in unemployment can be across the board rather than fall disproportionately on the unskilled, which is consistent with the evidence (see the references in footnote 3).

[6] This reasoning is similar to the intuition for why firms find it profitable to invest in the training of their employees in the presence of labour market imperfections in Acemoglu and Pischke (1999). It also relies on the notion that firms obtain some 'rents' from the employment relationship. In the absence of such rents, firms would simply lay off workers when their wages are pushed up.

[7] For this explanation, it is important that all these countries share the same world technology frontier. Otherwise, the market size effect emphasised in Acemoglu (1998) would introduce a countervailing effect; the decline in the relative employment of unskilled workers would discourage the development of technologies complementary to them.

Therefore, the overall macro predictions of this approach are consistent with cross-country trends. However, as yet there is no detailed evidence supporting this theory, and an empirical investigation of these ideas may be an interesting area for future research.

2. Cross-Country Relative Demand Shifts

2.1. *The Relative-Supply-Demand Framework*

I now develop the relative-supply-demand framework in more detail for a quantitative evaluation of the traditional explanation. Consider the following simple model (Welch, 1970; Katz and Murphy, 1992; Acemoglu, 2002*a*): there are two types of workers, unskilled (low-education) workers and skilled (high-education) workers. I denote the employment of unskilled and skilled workers in country j at time t by $L^j(t)$ and $H^j(t)$. These employment levels may vary across countries and over time both because of differences in the education levels of the population, and also because, in the presence of labour market distortions, there may be unemployment.

The aggregate production function for economy j takes the constant elasticity of substitution (CES) form

$$Y^j(t) = \{[A_l^j(t)L^j(t)]^\rho + [A_h^j(t)H^j(t)]^\rho\}^{1/\rho}, \tag{1}$$

where $\rho \leq 1$, and $A_l^j(t)$ and $A_h^j(t)$ are factor-augmenting technology terms, which are, for now, allowed to vary across countries. The elasticity of substitution between skilled and unskilled workers in this production function is $\sigma \equiv 1/(1/\rho)$.

Dropping time subscripts when this causes no confusion, the marginal product of the two factors can be written as

$$MP_L^j = (A_l^j)^\rho[(A_l^j)^\rho + (A_h^j)^\rho(H^j/L^j)^\rho]^{(1-\rho)/\rho}, \tag{2}$$

and

$$MP_H^j = (A_h^j)^\rho[(A_l^j)^\rho(H^j/L^j)^{-\rho} + (A_h^j)^\rho]^{(1-\rho)/\rho}.$$

Suppose that wages are related linearly to marginal product: $\omega_H^j = \beta MP_H^j$ and $\omega_L^j = \beta MP_L^j$. The case where $\beta = 1$ corresponds to workers being paid their full marginal product, with no rent sharing. Irrespective of the value of β, we have

$$\omega^j \equiv \frac{\omega_H^j}{\omega_L^j} = \frac{MP_H^j}{MP_L^j}.$$

That is, in this specification firms will be along their relative demand curves.

Throughout the paper, I will think of ω^j both as a measure of skill premium (such as returns to schooling) and as a measure of inequality. This is motivated by a reasoning whereby even among observationally equivalent workers some will be more 'skilled', and they will earn higher wages commensurate with their skills and the market price of skills as reflected by ω^j; see Juhn *et al.* (1993); Acemoglu (2002*a*). In practice, of course, there are many other factors, in addition to the returns to skills, determining wage dispersion among observationally identical workers.[8]

Alternatively, as long as firms are along their relative demand curve, the skill premium will be

$$\omega^j = \left(\frac{A_h^j}{A_l^j}\right)^{\rho} \left(\frac{H^j}{L^j}\right)^{-(1-\rho)} = \left(\frac{A_h^j}{A_l^j}\right)^{(\sigma-1)/\sigma} \left(\frac{H^j}{L^j}\right)^{-1/\sigma}. \tag{3}$$

Equation (3) can be rewritten in a more convenient form by taking logs,

$$\ln \omega^j(t) = \frac{\sigma-1}{\sigma} \ln\left[\frac{A_h^j(t)}{A_l^j(t)}\right] - \frac{1}{\sigma}\ln\left[\frac{H^j(t)}{L^j(t)}\right]. \tag{4}$$

This equation shows that the skill premium is decreasing in the relative supply of skilled workers, H^j/L^j, except in the special case where $\sigma \to \infty$ (where skilled and unskilled workers are perfect substitutes).

Another important point to note from this equation is that as long as $\sigma > 1$, i.e., as long as skilled and unskilled workers are gross substitutes, an increase in A_h^j/A_l^j corresponds to skill-biased technical change and raises the skill premium and wage inequality. Interestingly, when $\sigma < 1$, it is a decline in A_h^j/A_l^j that corresponds to skill-biased technical change (Acemoglu, 2002*a*). But the case with $\sigma < 1$ is not of great empirical relevance in the context of skilled and unskilled workers, since almost all existing estimates suggest that $\sigma > 1$ (Freeman, 1986; Hamermesh, 1993).

Let us start with a relatively weak form of the common technology assumption. In particular, suppose that

$$A_h^j(t) = \eta_h^j \theta^j(t) A_h(t) \quad \text{and} \quad A_l^j(t) = \eta_l^j \theta^j(t) A_l(t). \tag{5}$$

This assumption can be interpreted as follows. There is a world technology represented by $A_h(t)$ and $A_l(t)$, which potentially becomes more or less skill-biased over time. Countries may differ in their ability to use the world technology efficiently, and this is captured by the term $\theta^j(t)$. Although the ability to use world technology is time varying, it is symmetric between the two sectors. In addition, countries may have different comparative advantages in the two sectors as captured by the terms η_h^j and η_l^j (though these are assumed to be time invariant). These parameters η_h^j and η_l^j also capture differences in the productivity of workers in different skill categories, emphasised to be very important by Nickell and Bell (1996) and Leuven *et al.* (1999). The presence of these parameters in the model will also show that the inability of the relative-supply-demand framework, with common technology trends, to account for cross-country inequality trends is not primarily due to cross-country differences in skill categories.[9]

[8] See Acemoglu (1998) and Galor and Moav (2000) for models where technical change affects returns to education and within group wage dispersion differentially.

[9] In other words, the fact that high school graduates may be more skilled in Germany can explain why they earn more than American high school graduates. But by itself, it cannot explain why the college-high-school earnings ratio did not increase in Germany as it did in the US.

Substituting (5) into (4), we obtain

$$\ln \omega^j(t) = c^j + \ln a(t) - \frac{1}{\sigma}\ln\left[\frac{H^j(t)}{L^j(t)}\right], \tag{6}$$

where $\ln a(t) \equiv \dfrac{\sigma-1}{\sigma}\ln[A_h(t)/A_l(t)]$ is the measure of skill-biased technical change, and $c^j \equiv \dfrac{\sigma-1}{\sigma}\eta_h^j/\eta_l^j$ captures differences in comparative advantage and in the relative productivities of skilled and unskilled workers.

Notice that H^j/L^j is the relative employment of skilled and unskilled workers. An alternative way to write (6) is; see also Nickell and Layard (1999):

$$\ln \omega^j(t) = c^j + \ln a(t) - \frac{1}{\sigma}\ln\left[\frac{\bar{H}^j(t)}{\bar{L}^j(t)}\right] - \frac{1}{\sigma}\ln\left[\frac{1-u_h^j(t)}{1-u_l^j(t)}\right], \tag{7}$$

where $\bar{H}^j$ and $\bar{L}^j$ refer to the population of high- and low-skill workers of the right age bracket, and u_h^j and u_l^j refer to their nonemployment rates. This equation emphasises that, as discussed in Section 1, for a given technology trend, changes in skill premia can be accounted for either by changes in relative supplies of skills in the population or in relative (non)employment rates. In the rest of the paper, I will use (6), and will not distinguish between these two sources of variation in the relative employment of skilled individuals.

Now, using US data we can construct an estimate for the change in $\ln a(t)$, denoted by $\Delta \ln \hat{a}(t)$, using an estimate for the elasticity of substitution, σ as:

$$\Delta \ln \hat{a}(t) = \Delta \ln \omega^0(t) + \frac{1}{\sigma}\Delta \ln\left[\frac{H^0(t)}{L^0(t)}\right],$$

where $j = 0$ refers to the US. Although the elasticity of substitution between skilled and unskilled workers, σ, is difficult to pin down precisely, there is a fairly well-established consensus that it is greater than 1, perhaps around 1.4, but possibly as large as 2; see, Freeman (1986), Hamermesh (1993), Katz and Murphy (1992), Angrist (1995), Card and Lemieux (2001). Hence, in the empirical exercise I will use $\sigma = 1.4$ and $\sigma = 2$ as two reference values.

Now define Δ_k as the k-period difference operator, i.e.,

$$\Delta_k x \equiv x(t) - x(t-k).$$

Then, predicted changes in the skill premium for country j between $t-k$ and t are given by:[10]

$$\Delta_k \ln \hat{\omega}^j(t) = \Delta_k \ln \hat{a}(t) - \frac{1}{\sigma}\Delta_k \ln\left[\frac{H^j(t)}{L^j(t)}\right]. \tag{8}$$

[10] Equivalently, we can write:

$$\bar{\Delta} \ln \omega^j(t) = -\frac{1}{\sigma}\bar{\Delta}\ln\left[\frac{H^j(t)}{L^j(t)}\right].$$

where $\bar{\Delta}\ln x^j(t) \equiv \Delta \ln x^j(t) - \Delta \ln x^0(t)$ with $j = 0$ as the US, and investigate whether this equation provides a good fit to the data.

In this paper, the method of assessing the ability of the traditional approaches to explain cross-country inequality trends will be to compare the predicted skill premia changes, $\Delta_k \ln \hat{\omega}^j(t)$, to actual changes, $\Delta_k \ln \omega^j(t)$, for various values of the elasticity of substitution, σ.

The implicit assumption in this exercise is that there is no delay in the adoption of new technologies across countries. Instead, it is quite possible that some of the new skill-biased technologies developed or adopted in the US are only introduced in continental Europe with a lag. That is, instead of (5), we would have

$$A_h^j(t) = \eta_h^j \theta^j(t) A_h(t - k^j) \quad \text{and} \quad A_l^j(t) = \eta_l^j \theta^j(t) A_l(t - k^j),$$

implying that there is a delay of k^j periods for country j in the adoption of frontier technologies.

Motivated by the possibility of such delays, as an alternative method I use US data from 1974 to 1997 to recover estimates of $\Delta \ln \hat{a}(t)$, and calculate the average annual growth rate of $\ln \hat{a}(t)$, denoted by $\tilde{g}$. I then construct an alternate estimate for the predicted change in the skill premium in country j between dates $t-k$ and t as:

$$\Delta_k \ln \tilde{\omega}^j(t) = \tilde{g}k - \frac{1}{\sigma}\Delta_k \ln\left[\frac{H^j(t)}{L^j(t)}\right]. \tag{9}$$

In this exercise, I use 1974 as the starting point, since it is five years prior to the earliest observation for any other country from the LIS data, and five years appears as a reasonable time lag for diffusion of technologies among the OECD countries. I use 1997 as the final year, since this is the final year for which there is LIS data for a country in my sample.

Whether the relative-supply-demand framework provides a satisfactory explanation for cross-country inequality trends can then be investigated by comparing the predicted skill premium changes, the $\Delta_k \ln \hat{\omega}^j(t)$s from (8) and the $\Delta_k \ln \tilde{\omega}^j(t)$s from (9), to the actual changes, the $\Delta_k \ln \omega^j(t)$s.

3. Can Differences in Relative Supplies Explain Inequality Differences?

3.1. *Data*

I now undertake a preliminary investigation of whether differences in the behaviour of relative supplies can explain the differential inequality trends across countries. More specifically, I investigate whether (8) and (9) provide a good description of the cross-country inequality trends, I use data from Luxembourg Income Study (LIS) dataset; see for example, Gottschalk and Smeeding (1997) for an investigation of cross-country income inequality using this dataset, and Gottschalk and Joyce (1998) for an investigation of differences in wage inequality. Because LIS data for different countries refer to different years, I combine these with the March Current Population Surveys (CPS) for the corresponding years.

There are a number of difficulties in using the LIS for this purpose. First, information on educational attainment is missing for a number of countries. In particular, there is no consistent education information for the UK and Sweden, and for the Netherlands, the education categories change over the sample period in a way that makes it difficult to construct comparable relative supply numbers. Second, for some countries, for example, Belgium and France, incomes are reported after taxes. Third, because the LIS sample is limited to household heads, relative supplies have to be constructed for heads of households instead of the whole population. Finally, because weeks worked information is missing for some countries, annual earnings have to be used to construct skill (college) premia. These difficulties notwithstanding, the LIS provides a convenient data set for a preliminary look at whether differences in relative supplies could account for the differential inequality trends.

The skill premia are obtained from a log-wage regression analysis using annual earnings of full-time-full-year male household heads aged of 18–64. The 'college premium' is estimated as the coefficient on the dummy for college education. Following other authors, in the case where there is no education information, I use information on occupation (this is the case for the UK and Sweden, see the Appendix). The regression also contains other education dummies, a quartic in age (since experience cannot be constructed for every country), and a race or immigrant dummy when applicable (see the Appendix). For the CPS calculations, when earnings are top coded, they are assigned the value of 1.5 times the tope code.[11,12]

As the measure of relative supply I use in the employment of college graduates divided by the employment of those who are not college graduates. The working paper version, Acemoglu (2002*b*) reports results using measures of relative supply of college-equivalent workers constructed as in Autor *et al.* (1998).[13] The results are remarkably similar to those reported here.

When college information is not available, occupations are used for this calculation (see the Appendix).[14] For all calculations, I use a sample of male heads of households rather than the whole population, since the LIS only has information for heads of households. To the extent that there are differential trends over the years across different countries in female labour force participation, this limitation of the LIS may create biases in the analysis here.[15]

[11] Because the sample is narrower than usual (in particular, it excludes women), is not weighted by weeks worked, and includes age instead of experience controls, the college premium for the US is estimated to be lower than usual.

[12] In addition, the 90–10 wage differential shown in Table 1 is simply the log difference between the earnings of the household head at the 90th percentile and those of the household head at the 10th percentile (again the sample is limited to full-time-full-year male heads of households).

[13] That is, college equivalents = college graduates + 0.5 × workers with some college, and non-college equivalents = high school dropouts and graduates + 0.5 × workers with some college.

[14] For Germany, we only use data from 1989 and 1994. The survey also includes data for 1981 and 1984, but the 1981 survey is the first LIS survey, and data quality is low and LIS advises against the use of this survey. The 1984 survey has a very different classification of education, and implausibly few people outside the categories of high school and high school and less. Although I report overall wage inequality numbers from the survey in Table 1, I do not use it for calculating returns to schooling or relative supplies.

[15] From the US data, it is possible to check whether relative supplies calculated for male heads of households behave similarly to those calculated for the whole population. From the March CPS data over the same time period, the correlation coefficient between the two relative supplies is 0.9942. If we detrend the two measures, the correlation coefficient is still relatively high, 0.4737. This suggests that, at least in this US case, the restriction to male heads of households is not too problematic. I thank an anonymous referee for suggesting this calculation.

Because there are a number of problems with the French data (for example, incomes are reported after taxes, there is no education variable for the first two surveys, and it is not possible to limit the sample to full-time-full-year workers), I exclude France from the analysis. I also exclude Luxembourg since the sample size is small.

3.2. *Empirical Results*

Figures 3 and 4 show the results of the empirical exercise. Figure 3 depicts the estimates obtained from (8) for two values of the elasticity of substitution, $\sigma = 1.4$ and $\sigma = 2$, while Figure 4 shows the estimates from (9), again for the same two values of the elasticity of substitution. In all cases, the change estimates, $\Delta_k \ln \hat{\omega}^j(t)$ and the $\Delta_k \ln \tilde{\omega}^j(t)$, are translated into level estimates by choosing the first year estimate for each country to be the same as the actual skill premium for that country.

A number of patterns are apparent from the Figures, irrespective of which method and which estimate of the elasticity of substitution are used. First, for Australia and Canada, the predicted skill premia estimates are close to the actual estimates, while for the UK, the college premium increases more than predicted. Therefore, there is no evidence that the relative-supply-demand framework with common technology trends is predicting too large an increase in the skill premia

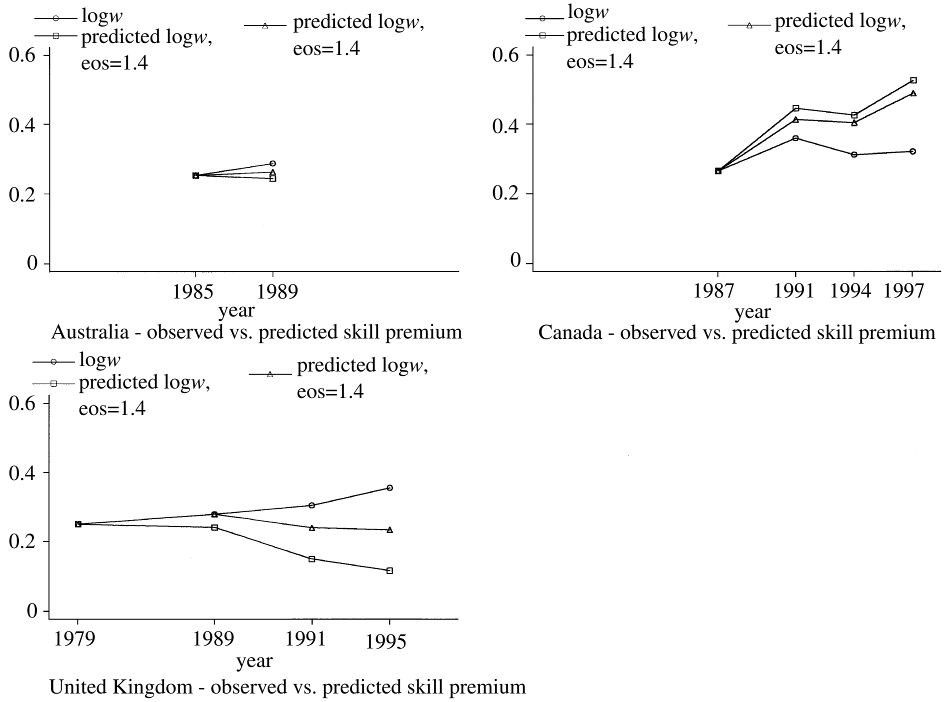

Fig. 3. *Actual Skill Premia and Predicted Skill Premia from (8) for* $\sigma = 1.4$ *and* $\sigma = 2$

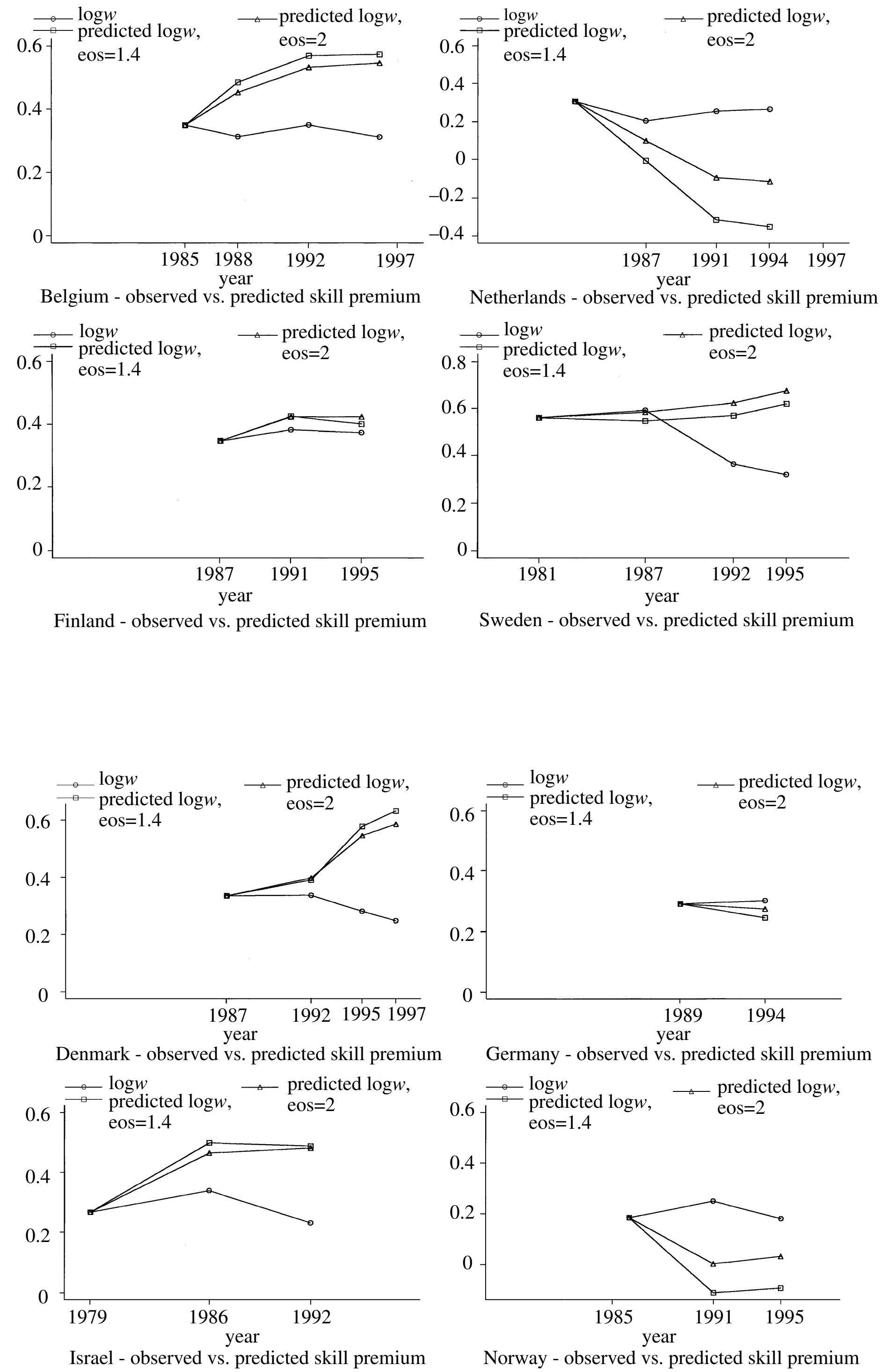

Fig. 3. *Continued*

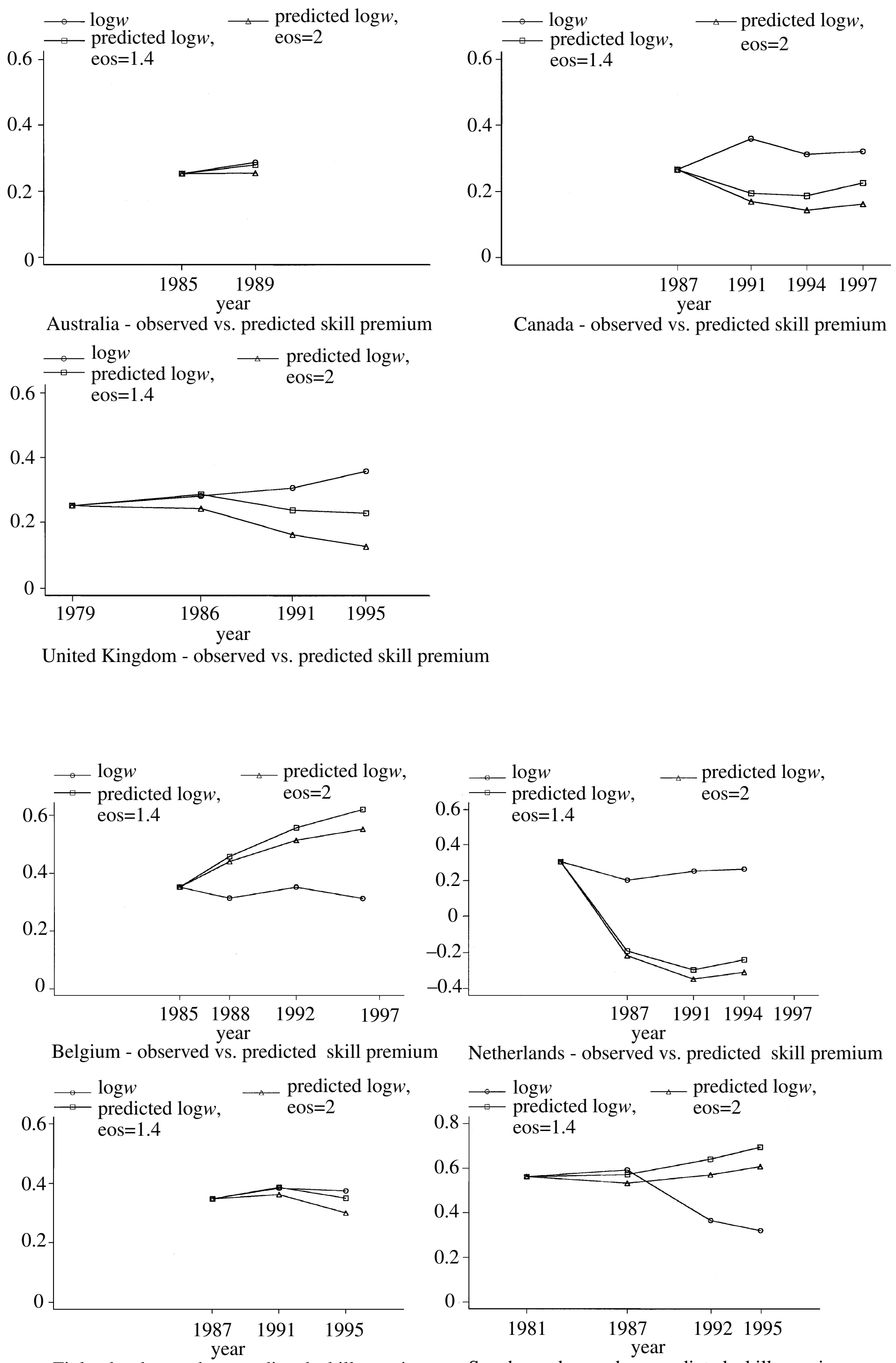

Fig. 4. *Actual Skill Premia and Predicted Skill Premia from (9) for $\sigma = 1.4$ and $\sigma = 2$*

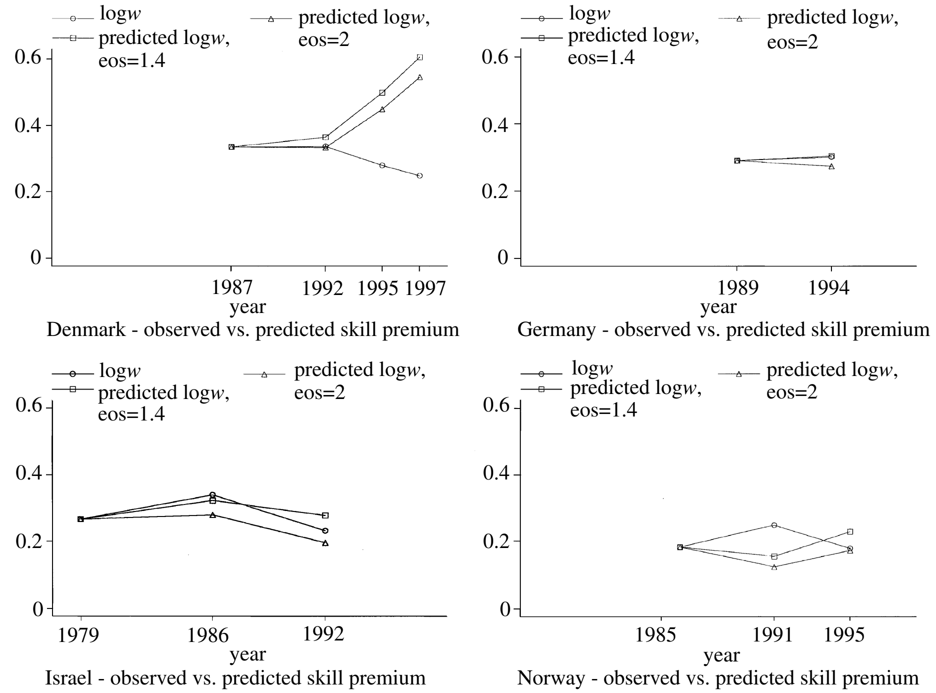

Fig. 4. *Continued*

among the Anglo-Saxon countries. This conclusion is consistent with the results of Katz *et al.* (1995), Murphy *et al.* (1998) and Card and Lemieux (2001).

Second, for the Netherlands, the predicted skill premia decline, whereas the actual skill premia remain approximately country. This reflects substantial increase in the relative supplies of skills in this constant. Given the shortcomings of the LIS data for the Netherlands noted above, increases in the relative supply of skills are likely to be overstated, and these results need to be interpreted with caution. Next, for Germany, Norway and Finland the predicted and actual skill premia move more or less in tandem. Hence, the relative-supply-demand framework with common technology changes appears to perform well for these countries, though it has to be borne in mind that German relative supply changes may be overstated in the LIS data.

Finally, for Belgium, Denmark and Sweden, the predicted skill premia estimates increase substantially while actual skill premia are approximately constant or actually decline. For Israel, the same result is obtained using the first method, but not the second. Given the quality of the LIS data, these results have to be viewed as preliminary, and more work using detailed microdata from these countries is necessary to reach more reliable conclusions. Nevertheless, the results suggest that for a significant fraction of the continental European countries in the sample, the relative-supply-demand framework with common technology trends does not provide an entirely satisfactory explanation for the differential behaviour of skill premia. Instead, it appears that relative demand for skills increased substantially less in Belgium, Denmark and Sweden than in the US or in other Anglo-Saxon countries.

4. A Model of Differential Technology Responses

I now develop a simple theory which links the adoption of skill-biased technologies to labour market institutions, and provides an explanation for why technical change may have been less skilled-biased in Europe than in the US. This theory builds on a framework I developed in Acemoglu (1999*a*), and combines it with some of the insights of the literature on training investments in the presence of labour market frictions, for example, Acemoglu (1997), Acemoglu and Pischke (1998, 1999).

The basic ideas is that in a labour market with wage bargaining, the incentives for firms to invest in new technologies is affected by the degree of wage compression. In particular, greater wage compression may increase firms' incentives to raise the productivity of low-skill workers. I then suggest that the greater institutional wage compression in Europe may have encouraged firms to adopt certain technologies with low-skill workers that US firms did not adopt.

Throughout, I will keep the presentation at a heuristic level. The reader is referred to Acemoglu (1999*a*) for a fuller discussion of a similar model (but without an analysis of the impact of differences in wage-setting institutions on technology choices).

4.1. *The Environment*

There is a continuum 1 of workers that are infinitely lived and maximise the net present value of income discounted at the rate r. A fraction ϕ of these workers are skilled, and have human capital h_s, while the remaining workers are unskilled with human capital $h_u < h_s$.

I endogenise job creation to discuss unemployment. Jobs in this economy are created via costly search as in the models by Diamond (1982), Mortensen (1982), and Pissarides (1990). When there are V vacancies and U unemployed workers, there will be $M(U,V)$ new matches created. Notice that what matters is the total number of unemployed workers (skilled plus unskilled), and as a result, both skilled and unskilled workers will have the same matching rates. I assume that the function M exhibits constant returns to scale, so matching rates are determined simply by the tightness of the labour market, $\theta = V/U$. The probability of matching with a worker for a vacancy is $q(\theta)$ where q is a decreasing function, which implies that when there are more vacancies chasing unemployed workers, each vacancy gets matched with a lower probability. The probability of matching for an unemployed worker, in turn, is $\theta q(\theta)$, which is assumed to be increasing in θ, so that unemployed workers find jobs more easily when there are more vacancies per worker. I also assume that matches between firms and workers come to an end at the exogenous probability s.

Firms incur a setup cost γ when they post a vacancy. Once they match with a worker, they decide what type of a job to create. In Acemoglu (1999*a*), I analysed the more realistic (and involved) case where firms decide the type of job before matching. Here I focus on the case where this decision is made after matching in order to simplify the analysis. Specifically, a firm matched with a worker of human capital h can either produce

$$Ah \tag{10}$$

units of the final good, without incurring any additional costs, or it can undertake an additional investment of cost k and produce

$$(1+\alpha)Ah, \tag{11}$$

where $\alpha > 0$.

One possible interpretation of the choice between the two technologies is that firms can either use last period's technology at no cost, or adopt the frontier technology by incurring an additional cost every period.

Notice that the multiplicative nature of the production function in (11) makes new technology 'complementary' to skills, in the sense that a better technology increases the productivity of a skilled worker more in absolute terms than that of an unskilled worker. Changes in α do not affect the ratio of the productivities of skilled and unskilled workers, however.

Also in terms of the framework discussed in the previous section, the elasticity of substitution between skilled and unskilled workers is infinity, and wage inequality is unaffected by relative supplies. This is to simplify the discussion and focus on differential technology responses of different economies.

4.2. *Analysis*

Denote the technology adoption decision $x \in \{0, 1\}$, with $x = 1$ corresponding to adoption. Then the discounted net present value of a firm with technology adoption decision x and matched with a worker of skill $h \in \{h_u, h_s\}$, $J^E(x, h)$, can be written as

$$J^E(x,h) = Ah + x(\alpha Ah - k) - w(x,h) + \frac{1}{1+r}\left[sJ^V + (1-s)\max_{x'} J^E(x',h)\right] \tag{12}$$

where $w(x,h)$ is the wage as a function of the technology decision and the skill level of the worker, and J^V is the value of a vacancy in the next period. Throughout I limit the analysis to steady state, so these values are not time varying. The wage may depend on the technology decision because of bargaining over the quasi-rents created by search frictions. The term sJ^V is added because with probability s, there is a separation, and the firm becomes an unfilled vacancy. Finally, the last term is the continuation value conditional on no separation, and I have imposed that there will be no voluntary separations. This will be the case in steady state.[16]

[16] Away from the steady state, workers may want to end their relationship with a firm that does not adopt the new technology voluntarily, and I am ignoring this case in writing (12). In any case, such voluntary separations would never happen along the equilibrium path, since the technology adoption decisions are taken every period, so the firm would never choose not to adopt the new technology when it knows that this will result in a quit.

In addition, I assume that wages are equal to a fraction β of the worker's *ex post* product:[17]

$$w(x, h) = \beta(1 + x\alpha)Ah. \tag{13}$$

The important element incorporated in this expression is that wage determination takes place after the firm *sinks* the cost of new technology. This is reasonable in practice given the impossibility of writing binding wage contracts, and that, while wages are negotiated throughout the duration of the employment relationship, many of the technology-related decisions are made before or at the beginning of this relationship.

The steady-state value of a job that always follows technology adoption decision x can be written as:

$$J(x, h) = \delta[(1 - \beta)(1 + x\alpha)Ah - xk] \tag{14}$$

where $\delta \equiv (1 - s)/(1 + r)$ is the effective discount factor, taking into account time preference and separation probability.

Notice that the firm only receives a fraction $1 - \beta$ of the output, though it incurs the full cost of investment. As a result, firms will tend to underinvest in technology. This is a standard result, going back at least to Grout (1984), and also emphasised in the context of search equilibrium by Acemoglu (1996).

It is straightforward to see that, in steady state, firms will choose to adopt the new technology with a worker of skill level h if and only if $J(x = 1,h) > J(x = 0,h)$, or if

$$(1 - \beta)\alpha Ah > k. \tag{15}$$

The fact that the left-hand side of this expression is increasing in h reiterates that new technologies are complementary to skills, and therefore more likely to be adopted with skilled workers.

Next, consider the case:

$$(1 - \beta)\alpha Ah_u > k. \tag{16}$$

This condition ensures that firms are happy to adopt the new technology even with unskilled workers. Clearly (16) immediately implies that $(1 - \beta)\alpha Ah_s > k$. So the new technology will be adopted with skilled workers as well. Then, wages will be given by

$$w^u = \beta(1 + \alpha)Ah_u \quad \text{and} \quad w^s = \beta(1 + \alpha)Ah_s, \tag{17}$$

so the skill premium (or the measure wage inequality) in each period is simply

$$w \equiv \frac{w^s}{w^u} = \frac{h_s}{h_u}.$$

[17] More formally, I am assuming that wages are determined by outside-option bargaining as in Rubinstein (1982) and Shaked and Sutton (1984); see Acemoglu (1996) for a justification in the search equilibrium context.

It is straightforward to verify that if A increases at a constant rate over time, and new technologies continue to be adopted with both of skilled and unskilled workers, wages for both groups of workers increase at a constant rate, and wage inequality remain stable (Acemoglu, 2002*b*). This can be thought of as technical change that is 'neutral' towards skills.

It is also straightforward to characterise the equilibrium tightness of the labour market and the unemployment rate. In particular, given condition (17), the value of a vacancy at time t can be written as:[18]

$$J^V = -\gamma + q(\theta)\Big\{\phi \max\big[J^E(x=1,h_s);\ J^E(x=0,h_s)\big] \\ + (1-\phi)\max\big[J^E(x=1,h_u);\ J^E(x=0,h_u)\big]\Big\} + [1-q(\theta)]\max[J^V;0]. \quad (18)$$

Here γ is the cost of opening a vacancy. With probability $q(\theta)$, the vacancy matches with a worker, and with probability ϕ, this worker is skilled, and with probability $1-\phi$, he is unskilled. The firm then decides whether to adopt the new technology or not as captured by the 'max' operators. With probability $1-q(\theta)$, there is no match, and then the firm decides whether to keep the vacancy, obtaining the value J^V or shut down.

Now imposing free entry into creating vacancies, i.e., $J^V = 0$, and using (14), we obtain:

$$J^V = -\gamma + q(\theta^{\text{Pre}})\{\delta[(1-\beta)(1+\alpha)A - k][\phi h_s + (1-\phi)h_u]\} = 0, \quad (19)$$

where θ^{Pre} is the steady-state tightness of the labour market, with the superscript 'Pre' denoting the fact that this refers to the case before the technology shock. This tightness and the whole equilibrium allocation are defined uniquely.

Next, the steady state unemployment rate for both skilled and unskilled workers is:[19]

$$u = \frac{s}{s + \theta q(\theta)}. \quad (20)$$

The important point is that both skilled and unskilled workers have the same unemployment rate, and that this unemployment rate is a decreasing function of θ: unemployment will be lower when the labour market is tighter.

[18] Without loss of any generality, I am using the timing convention that a vacancy that gets filled this period can start production in this period, and faces no immediate possibility of a separation.

[19] This unemployment rate equation follows by equating to the flow out of unemployment, $\theta q(\theta)u$, to the flow into unemployment, $(1-s)u$. The fact that both types of workers have the same unemployment rate is a consequence of the simplifying assumption that all search is undirected, and no matches are turned down. It is straightforward, but cumbersome to generalise the model by adding some heterogeneity, or by allowing firms to turn down workers as in Acemoglu (1999*a*).

4.3. *Change in Technology Regime*

Now imagine that the economy is hit by an adverse shock, increasing k to $k' > k$.[20] Assume also that following this technology shock, we have:

$$(1-\beta)\alpha A h_s > k' > (1-\beta)\alpha A h_u. \tag{21}$$

Condition (21) implies that firms, from this point onwards, will continue to adopt the new technology with skilled workers, *but not* with unskilled workers. That is, the new technology adoption condition (15) is now satisfied for skilled workers only. As a result, wages are now

$$w^u = \beta A h_u \quad \text{and} \quad w^s = \beta(1+\alpha)A h_s,$$

so after this technology shock, wage inequality increases to

$$\omega' \equiv \frac{w^s}{w^u} = (1+\alpha)\frac{h_s}{h_u}.$$

In addition, unemployment for both types of workers increases. To see this note that the free-entry condition now changes to

$$J^V = -\gamma + q(\theta^{\text{US-Post}})(\delta\{\phi[(1-\beta)(1+\alpha)A - k]h_s + (1-\phi)(1-\beta)A h_u\}) = 0, \tag{22}$$

which incorporates the fact that now firms will not adopt the new technology with unskilled workers. The steady-state labour market tightness is denoted by $\theta^{\text{US-Post}}$, since it refers to the equilibrium after the change in technology in the model economy supposed to approximate the US.

Comparing this expression to (19) shows that, as a consequence of the technology change, opening a vacancy is now less profitable (i.e. the term in braces has fallen in value). So θ, the tightness of the labour market, has to decline to satisfy (22) – that is, $\theta^{\text{US-Post}} < \theta^{\text{Pre}}$. This implies, from (20), that the unemployment rate will increase.[21]

So at a very simple level, this model illustrates how a technological shock might increase wage inequality by changing the technology adoption decisions of firms. After the change in technology, firms find it profitable to invest in new

[20] Notice that I am taking the technology shock to be an increase in the cost of new investment. This amounts to assuming that there was a technological regime change making the rate of improvement of new technologies slower today than in the 1950s and 1960s. Although this runs counter to the general belief among economists who view the 1980s as times of rapid technological advances (Caselli, 1999; Greenwood and Yorukoglu, 1997; Hornstein and Krusell, 1996; Galor and Moav, 2000), it is quite plausible. Notice, for example, the widespread slowdown in the rate of growth of TFP and the evidence that industries adopting many of these new technologies had slower than usual productivity growth (Brendt *et al.*, 1994). Moreover, as Gordon (1998) argues it seems plausible that the new technologies of the 1980s and the 1990s, such as computers and information technology, may not have improved our productive capacity as much as the great inventions of the late 19th and early 20th centuries, including electricity, internal combustion, new chemicals and plastics and entertainment. See Gordon (1998), Jorgensen and Stiroh (2000) and the discussion in Acemoglu (2002*a*).

[21] This is consistent with the fact that unemployment both among low and high education workers in the US increased during the 1980s (Acemoglu, 1999*a*).

technologies only with skilled workers, and as a result, the relative productivity of skilled workers and the skill premium increase.

4.4. *Change in the Technology Regime in the 'European' Equilibrium*

Now, consider a different environment, meant to proxy at a very crude level the continental European labour market. In this environment, there is institutionally imposed wage compression, for example because of union-imposed wage floors or a binding minimum wage. This contrast captures in a stylistic way the differences between the American and continental European labour markets.[22]

Denote the wage floor implied by union-wage setting or minimum wages by $\underline{w}$. To illustrate the main point, it is most convenient to assume:

$$\beta(1+\alpha)Ah_u > \underline{w} > \beta Ah_u \quad \text{and} \quad \beta Ah_s > \underline{w}. \tag{23}$$

The wage floor $\underline{w}$ is binding for a firm that hires an unskilled worker and does not adopt the new technology. In contrast, it is not binding for a firm that adopts the new technology with an unskilled worker. It is never binding for a firm employing a skilled worker.

In the presence of the wage floor, the wage equation (13) cannot apply, since (23) implies that some workers would be paid less than the wage floor $\underline{w}$. Hence, consider a straightforward generalisation of this wage equation to:[23]

$$w(x,h) = \max[\beta(1+x\alpha)Ah, \underline{w}]. \tag{24}$$

So if the 'equilibrium bargained wage' in the absence of the wage floor is below the floor, the worker is simply paid this wage floor. Since nothing has changed for skilled workers, the condition for the new technology to be adopted is the same as in the unregulated economy, i.e., $(1-\beta)(1+\alpha)Ah_s > k$.

But the technology decision for unskilled workers has changed. In particular, now the wage floor will be binding for a firm employing an unskilled worker with the old technology, so

$$J(x=0,h_u) = \delta(Ah_u - \underline{w}). \tag{25}$$

In contrast, the value of the firm that adopts the new technology with an unskilled worker is still given by

$$J(x=1,h_u) = \delta[(1-\beta)(1+\alpha)Ah_u - k], \tag{26}$$

because, when the firm adopts the new technology, the wage floor is not binding. Comparing the expressions (25) and (26) shows that the firm will find it profitable to introduce the new technology with an unskilled worker if

[22] For example, Blau and Kahn (1996) provide evidence in favour of the hypothesis that labour market regulations compress wage differences at the bottom of the distribution in Europe. They show that although wage differentials between the 90th and the 50th wage percentiles are similar across countries, the differential between the 50th and 10th percentiles is much larger in the US than Europe. Union wage setting, which extends wage floors across firms, or relatively high minimum wages, as well as more generous social insurance programmes, are probably at the root of this wage compression.

[23] This wage rule follows from a straightforward application of the Rubinstein (1982) bargaining model with outside options (see Shaked and Sutton, 1984).

$$(1-\beta)\alpha Ah_u - k > \beta Ah_u - \underline{w}. \tag{27}$$

Assumption (23), which meant that the wage floor was binding for unskilled workers, also immediately ensures that the right hand-side of (27) is negative. Consequently, the condition for this economy to adopt new technologies with unskilled workers is less restrictive than for the unregulated economy (recall the unregulated economy adopts the new technology when $(1-\beta)\alpha Ah_u - k > 0$).

The intuition is as follows: the institutions already force the firm to pay an unskilled worker a higher wage than what the firm and the worker would have bargained to. This implies that the firm can invest more and increase production, without this increased productivity being translated into higher wages. Wage compression is therefore making the firm *the residual claimant* of the increase in the productivity of the worker.

This reasoning is similar to the intuition for why firms find it profitable to invest in the general training of their employees in the presence of labour market imperfections in Acemoglu and Pischke (1999). Also as in Acemoglu and Pischke (1999), labour market rents for firms are crucial for this result. With $\beta = 1$, that is, when there are no rents for firms, if institutions pushed the wages of unskilled workers up, firms would lay off all unskilled workers.[24]

Next imagine a situation in which firms invest in new technology with both skilled and unskilled workers, even in the absence of the wage floor. Then, *a fortiori*, firms in the 'European' equilibrium will also invest in new technology with both types of workers. Next, as discussed in subsection 4.3, imagine a change in technology regime, increasing the cost of investment from k to k', such that in the absence of the wage floor, firms stop investing in the new technology with unskilled workers. Because the wage floor increases the incentives to invest in new technology with unskilled workers, it is quite possible that the economy with wage compression will continue to do so. In particular, if

$$(1-\beta)\alpha Ah_u - \beta Ah_u + \underline{w} > k' > (1-\beta)\alpha Ah_u, \tag{28}$$

the new technology will be adopted with unskilled workers in Europe, but not in the US. Therefore, this model offers a possible explanation for why technical change may have been less skill biased in Europe than in the US over the past 20 years. Interestingly, in this simple model, not only is there less skill-biased technical change in Europe than in the US, but in fact, there is none. As a result, while the skill premium increases in the US, it remains unchanged in Europe.[25]

In light of these results, it is interesting that the brief empirical investigation above indicated similar relative demand shifts in other Anglo-Saxon countries. Since there is little institutional wage compression in these Anglo-Saxon countries, the analysis here suggests that firms there should have no further incentives to

[24] Of course, in this case we also need $\gamma = 0$ for firms to break even in the first place.

[25] The reader might note that the assumption of rent-sharing in the US economy is important for these results. Without rent-sharing, whenever the European economy with wage compression finds it profitable to adopt the new technology, so will US firms. This is not essential for the overall argument, however. It is possible to generalise (and complicate) the model such that wage compression forces European firms to invest in new technologies with unskilled workers, even when the competitive economy would not introduce these new technologies.

adopt new technologies with unskilled workers than US firms. Relative demand shifts in favour of skilled workers should be slower only in economies with significant institutional wage compression, such as the continental European economies.[26]

What about unemployment in the 'European' equilibrium after the change in the technology regime? Since firms are now adopting the new technology with both skilled and unskilled workers, the free-entry condition becomes:

$$J^V = -\gamma + q(\theta^{\text{E-Post}})(\delta\{[(1-\beta)(1+\alpha)A - k][\phi h_s + (1-\phi)h_v]\}) = 0. \tag{29}$$

Recall that in the absence of the wage floor, firms did not find it profitable to adopt the new technology with unskilled workers, so the term in braces is lower in (29) than the comparable term in expression (22). Therefore, $\theta^{\text{US-Post}}$ implied by (22) has to be higher than $\theta^{\text{E-Post}}$ implied by (29), and the technology shock will increase unemployment more in Europe than in the US. The intuition for this result is that wage compression is forcing firms to adopt new technologies with unskilled workers, while without wage compression firms would have preferred not to adopt these technologies. This implies that wage compression reduces profits from employing unskilled workers. Since each vacancy may be matched with either a skilled or an unskilled worker, wage compression discourages job creation in general, increasing both skilled and unskilled unemployment. This pattern of high unemployment both among the skilled and the unskilled in Europe is consistent with the broad facts.[27]

Overall, the theory presented here is consistent with the differential inequality trends across countries, the differential behaviour of the relative demand for skills, as documented in the first part of this paper, and with the fact that unemployment in Europe increased relative to that in the US over the 1980s. But as yet, there is no micro evidence supporting the underlying mechanism of this story.[28]

5. Concluding Remarks

Despite the social importance of inequality trends, and their prominence in academic debates, the economics profession currently lacks a consensus on why, over the past several decades, inequality increased in the US and the UK, but not in continental Europe.

In this paper, I reviewed the two traditional explanations for theses patterns, that relative supply of skills increased faster in Europe and European labour

[26] Additional implications are that following the change in technology regime, output should decline more in the US equilibrium, and TFP should decline more in the European equilibrium. This is because Europeans are producing using a more productive technology with unskilled workers, but this is something that is not profitable without the wage floor.

[27] Notice that if the model is modified so that firms can open separate vacancies for skilled and unskilled workers, only unskilled unemployment will increase. Nevertheless, it is important to see that the model, under some assumptions, can generate increases in the unemployment rates for both types of workers, contrasting with standard reasoning based on the Krugman hypothesis, which unambiguously predicts that it is unskilled unemployment that should increase.

[28] Interestingly, the evidence in Card *et al.* (1996) is consistent with the notion that the use of computers in the workplace is less concentrated in the high-education group in France than in the US.

market institutions prevented inequality from increasing, and I developed a simple framework to assess quantitatively whether these explanations account for a large fraction of the differential cross-country inequality trends I concluded that, although these traditional explanations account for a large fraction of the cross-country inequality trends, they do not provide an, entirely satisfactory picture. Instead, it appears that relative demand for skills also increased differentially across countries.

Motivated by this fact, I developed a simple theory where labour market institutions creating wage compression in Europe also encourage more investment in technologies increasing the productivity of less-skilled workers. This may have led to a smaller increase in the demand for skills over the past 20 years in Europe than in the US.

I showed that this explanation based on the effect of labour market institutions on technology adoption is consistent with the differential inequality trends, the differential behaviour of the relative demand for skills documented in the first part of the paper, and the differential behaviour of unemployment rates in Europe and the US.

These macro facts of course do not establish that this theory is along the correct lines, and there can be many other potential theories explaining why relative demands change differentially across countries. There are therefore both important theoretical and empirical avenues to pursue. I hope that this paper will stimulate others to investigate alternative approaches with differential degrees of skill-biased technology across countries (resulting from differential adoption decisions).

On the empirical front, work using microdata is necessary to investigate more carefully whether differences in relative supplies, with similar shifts in relative demands, can account for the differences in these cross-country inequality trends. Future work could also look at whether there is any direct evidence that technical change has been less skill biased in Europe than in the US. One possibility is to look at the rates of technology adoption and/or at rates of productivity growth and capital accumulation in unskill-intensive industries in Europe relative to similar industries in the US (using skill-intensive industries in both set of countries as a control group). Alternatively, one could undertake a direct investigation of whether certain advanced technologies, such as personal computers, computer-assisted or numerically-controlled machines, used seldom with unskilled workers in the US, were introduced with unskilled workers in Europe. Finally, it may also be fruitful to use data on industry-level skill-upgrading across different countries and expand the approach used in Berman *et al.* (1998) to obtain alternative estimates of relative demand shifts across countries.

On the theory front, it would be useful to investigate alternative explanations for why relative demand for skills may have changed differentially in different countries, including theories where the economy may function off its relative demand curve.

Finally, the current paper has focused on the causes of differential inequality trends among OECD economies. Another important and potentially exciting area is the study of inequality trends in middle-income and low-income nations.

Berman and Machin (2000) document a rapid increase in the demand for skills in middle-income countries, and a number of studies find increasing inequality in many developing countries, for example, Freeman and Oostendorp (2000) or Duryea and Szekely (2000). An investigation of the causes of the increase in inequality in developing countries over this same period is also an important research area.

MIT

Data Appendix

The samples come from the Luxembourg Income Studies Database (LIS). The LIS data is a collection of micro datasets obtained from annual income surveys in various countries. While these surveys are similar in form to the Current Population Survey for the US and extensive effort has been made to make information on income and household characteristics comparable across countries, important problems of comparability remain. In order to maintain consistency across countries, several restrictive criteria have been used when defining variables and samples. Following Gottschalk and Joyce (1998), who also used LIS data, a simple count of the number of workers, not weighted by weeks worked, is used as a measure of supply from each educational group. Moreover, the data is restricted to male heads of households, since the earnings of other individuals is not available for all survey years in all countries. Countries for which data on gross wages were not available were discarded, as were data from countries with only one survey in the LIS data base. In addition, for the reasons explained in the text, we do not use the German surveys for 1981 and 1984. As a result, at the end this study uses data from Australia (1985 and 1989), Belgium (1985, 1988, 1992 and 1996), Canada (1987, 1991, 1994 and 1997), Denmark (1987, 1992, 1995 and 1997), Finland (1987, 1991 and 1995), Germany (1989 and 1994), Israel (1979, 1986 and 1992), the Netherlands (1983, 1987, 1991 and 1994), Norway (1986, 1991 and 1995), Sweden (1981, 1987, 1992 and 1995), the United Kingdom (1979, 1986, 1991 and 1995). Data for the US in all those years comes from the March CPSs.

The college premium is, generally, the coefficient on workers with a college degree or more relative to high school graduates in a regression of log real annual gross wages. Specifically, four education categories were constructed, conceptually corresponding to less-than 12 years of education (high school dropouts), 12 years (high school graduates), 13 to 15 years (some college), and 16 or more years (college graduates) for the US. The recoding into these groups is straightforward in countries and years where the education variable is measured in years of schooling (these are: Israel, Canada and Finland, at least for some years), but somewhat more problematic for countries where the education variable is already grouped (all the rest, except Sweden and the UK). Since no education information is available in the LIS data base for Sweden and the UK, returns to broad occupations are used rather than education. Three occupation groups are constructed for those samples, roughly corresponding to professional and managerial workers, blue collar workers and a residual category which includes lower-level white-collar workers. The regression also includes dummies for the remaining education/occupation categories and a quartic in age – since the exact number of years of schooling would have to be inputed for most surveys, a quartic in age, and not experience, is used as a control in the wage regression. Only full-time, full-year workers aged 18 to 64 are used in these computations. Full-time workers are defined as those whose hours of work per week were no less than 35, and full-year workers are defined as those who worked at least 48 weeks per year. The samples also leave out those observations with the lowest 1% earnings. Finally, earnings for top coded observations are calculated as the value of the top code times 1.5.

The relative supply of skills is calculated from samples that include all wage and salary workers between the ages of 18 and 64. It is defined as the ratio of college graduate employment to the employment of all other workers.

References

Acemoglu, Daron (1996). 'A microfoundation for social increasing returns in human capital', *Quarterly Journal of Economics*, vol. 111, pp. 779–804.

Acemoglu, Daron (1997). 'Training and innovation in an imperfect labor market', *Review of Economic Studies*, vol. 64, pp. 445–64.

Acemoglu, Daron (1998). 'Why do new technologies complement skills? Directed technical change and wage inequality', *Quarterly Journal of Economics*, vol. 113, pp. 1055–90.

Acemoglu, Daron (1999*a*). 'Changes in unemployment and wage inequality: an alternative theory and some evidence', *American Economic Review*, vol. 89, pp. 1259–78.

Acemoglu, Daron (1999*b*). 'Patterns of skill premia', NBER Working Paper no. 7018.

Acemoglu, Daron (2002*a*). 'Technical change, inequality and the labor market', *Journal of Economic Literature*, vol. 40 (March), pp. 7–72.

Acemoglu, Daron (2002*b*). 'Cross-country inequality trends', NBER Working Paper no. 8832.

Acemoglu, Daron and Pischke, Jörn-Steffen (1998). 'Why do firms train? Theory and evidence', *Quarterly Journal of Economics*, vol. 113, pp. 79–119.

Acemoglu, Daron and Pischke, Jörn-Steffen (1999). 'The structure of wages and investment in general training', *Journal of Political Economy*, vol. 107, pp. 539–72.

Angrist, Joshua (1995). 'The economic returns to schooling in the West Bank and Gaza Strip', *American Economic Review*, vol. 85, pp. 1065–87.

Autor, David, Katz, Lawrence and Krueger, Alan B. (1998).'Computing inequality: have computers changed the labor market', *Quarterly Journal of Economics*, vol. 113, pp. 1169–214.

Beaudry, Paul and Green, David (2000). 'The changing structure of wages in the US and Germany: what explains the differences?', NBER Working Paper no. 7697.

Berman, Eli, Bound, John and Griliches, Zvi (1994).'Changes in the demand for skilled labor within US manufacturing industries: evidence from the annual survey of manufactures', *Quarterly Journal of Economics*, vol. 109, pp. 367–85.

Berman, Eli, Bound, John and Machin, Stephen (1998). 'Implications of skill-biased technological change: international evidence', *Quarterly Journal of Economics*, vol. 113, pp. 1245–80.

Berman, Eli, and Machin, Stephen (2000). 'Skill-biased technology transferred around the world', *Oxford Review of Economic Policy*, vol. 16, pp. 12–22.

Blanchflower, David, G, Oswald, Andrew, J and Sanfey, Peter (1997).'Wages, profits and nut-sharing', *Quarterly Journal of Economics*, vol. 111, pp. 227–51.

Blau, Francine D. and Kahn, Lawrence M. (1996). 'International differences in male wage inequality: institutions versus market forces', *Journal of Political Economy*, vol. 104, pp. 791–837.

Brendt, Ernie, Morrison, Catherine and Rosenblum, Larry (1994). 'High-tech capital formation and labor composition in U.S. manufacturing industries: an exploratory analysis', *Journal of Econometrics*, vol. 65, pp. 9–43.

Card, David, Kramartz, Francis and Lemieux, Thomas (1999). 'Changes in the relative structure of wages and employment: a comparison of the United States, Canada and France', *Canadian Journal of Economics*, vol. 32, pp. 843–77.

Card, David and Lemieux, Thomas (2001). 'Can falling supply explain the rising return to college for younger men?', *Quarterly Journal of Economics*, vol. 116, pp. 705–46.

Caselli, Francesco (1999). 'Technological revolutions', *American Economic Review*, vol. 87, pp. 78–102.

Diamond, Peter (1982). 'Wage determination and efficiency in search equilibrium', *Review of Economics Studies*, vol. 49(2), pp. 217–27.

Duryea, Suzanne and Szekely, Miguel (2000). 'Labor markets in Latin America: a look at the supply-side', *Emerging Markets Review*, vol. 1, pp. 199–228.

Freeman, Richard (1986). 'Demand for education', Ch. 6 in (Orley Ashenfelter and Richard Layard, eds.) *Handbook of Labor Economics*, Vol I, pp. 57–386, Amsterdam: North Holland.

Freeman, Richard and Katz, Lawrence F. (1995). 'Introduction and summary', in (R. Freeman and L. Katz, eds.), *Differences and Changes in Wage Structures*, pp. 1–22, Chicago, IL: The University of Chicago Press.

Freeman, Richard and Oostendorp, Remco (2000). 'Wages around the world: pay across occupations and countries', NBER Working Paper no. 8058.

Galor, Oded and Moav, Omer (2000). 'Ability biased technological transition, wage inequality and economic growth', *Quarterly Journal of Economics*, vol. 115, pp. 469–98.

Gordon, Robert (1998). 'Current productivity puzzles from a long-term perspective', Northwestern University, mimeo.

Gottschalk, Peter and Smeeding, Timothy M. (1997). 'Cross-national comparisons of earnings and income inequality', *Journal of Economic Literature*, vol. 35, pp. 633–87.

Gottschalk, Peter and Joyce, Mary (1998). 'Cross-national differences in the rise in earnings inequality: market and institutional factors', *Review of Economics and Statistics*, vol. 80, pp. 489–502.

Greenwood, Jeremy and Yorukoglu, Mehmet (1997). '1974', *Carnegie-Rochester Conference Series on Public Policy*, vol. 46, pp. 49–95.

Groshen, Erica (1991). 'Sources of wage dispersion: how much do employers matter', *Quarterly Journal of Economics*, vol. 106, pp. 869–84.

Grout, Paul (1984). 'Investment and wages in the absence of binding contracts: a Nash bargaining approach', *Econometrica*, vol. 52, pp. 449–60.

Hamermesh, Daniel (1993). *Labor Demand*, Princeton: Princeton University Press.

Hornstein, Andres and Krusell, Per (1996). 'Can technology improvements cause productivity slowdowns?', *NBER Macroeconomic Annual*, vol. 11, pp. 209–59.

Jorgensen, Dale W. and Stiroh, Kevin J. (2000). 'Raising and speed limit: U.S economic growth in the information age', forthcoming in the *Brookings Papers on Economic Activity.*

Juhn, Chinhui, Murphy, Kevin M. and Pierce, Brooks (1993). 'Wage inequality and the rise in returns to skill', *Journal of Political Economy*, vol. 101, pp. 410–42.

Katz, Lawrence and Autor, David (1999). 'Changes in the wage structure and earnings inequality', in (Orley, Ashenfelter and David Card, eds.), *The Handbook of Labor Economics* Volume III, Amsterdam: Elsevier.

Katz, Lawrence and Murphy, Kevin (1992). 'Changes in relative wages: supply and demand factors', *Quarterly Journal of Economics*, vol. 107, pp. 35–78.

Katz, Lawrence, Loveman, Gary W. and Blanchflower, David G. (1995). 'A comparison of changes in the structure of wages in four OECD countries', in (Richard Freeman and Lawrence Katz eds.) *Differences and changes in Wage Structures*, Chicago: University of Chicago Press.

Katz, Lawrence and Summers, Lawrence (1989). 'Industry rents: evidence and implications', *Brookings papers on Economic Activity (Macroeconomics)*, vol. 51, pp. 209–90.

Krueger, Alan B. and Pischke, Jörn-Steffen (1998). 'Observations and conjectures on the U.S. employment miracle', NBER Working Paper no. 6146.

Krugman, Paul (1994). 'Part and prospective causes of high unemployment', in Federal Reserve Bank of Kansas City *Reducing Unemployment: Current Issues and Policy Operations.*

Leuven, Edwin, Oosterbeek, Hessel and Van Ophem, Hans (1999). 'Explaining international differences in male wage inequality by differences in demand and supply of skills', Center for Economic Performance working paper.

Mortensen, Dale (1982). 'Property rights and efficiency in mating, racing and related games', *American Economic Review*, vol. 72, pp. 968–79.

Murphy, Kevin M. and Riddell, W. Graig and Romer, Paul M. (1998). 'Wages, skills and technology in the United States and Canada', in (E. Helpman, ed.) *General Purpose Technologies* Cambridge, MA: MIT Press.

Nickell, Stephen and Bell, Brian (1996). 'The collapse in demand for the unskilled and unemployment across the OECD', *Oxford Review of Economic Policy*, vol. 11, pp. 40–62.

Nickell, Stephen and Layard, Richard (1999). 'Labor market institutions and economic performance' in (Orley Ashenfelter and David Card, eds.), *The Handbook of Labor Economics*, Volume III, Amsterdam: Elsevier.

OECD (1994). *Jobs Study*, vols. 1 and 2, Paris.

Pissarides, Christopher (1990). *Equilibrium Unemployment Theory*. Cambridge, MA: Basil Blackwell.

Rubinstein, Ariel (1982). 'Perfect equilibrium in a bargaining model', *Econometrica*, vol. 50, pp. 97–109.

Shaked, Avner and Sutton, John (1984). 'Involuntary unemployment as a perfect equilibrium in a bargaining model', *Econometrica*, vol. 52, pp. 1341–64.

Welch, Finis (1970). 'Education in production', *Journal of Political Economy*, vol. 78, pp. 312–27.